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Dissertation Summary

Spectrophotometric Evolution of Old Stellar Systems

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Theoretical integrated spectrophotometric quantities, such as spectral line indices in the Lick system (Hβ, Mg$_2$, Mg b, Fe5270, Fe5335), broadband color indices (in the $UBVRIHK$ and Washington CMT_1 bandpasses), and surface brightness fluctuation (SBF) magnitudes and colors, ranging from far-UV to near-IR have been consistently computed for simple stellar populations from our evolutionary population synthesis code. The age range of -4 Gyr $\leq \Delta$t $\leq +4$ Gyr is explored, where Δt $= 0$ Gyr is the currently favored mean age of inner halo Galacitc globular clusters (GCs) (Galactocentric radius ≤ 8 kpc), $\sim$ 12Gyr. The main aim of this dissertation is to investigate the effects of post-red giant branch (post-RGB) stars on the integrated spectrophotometric quantities after employing detailed systematic variation of horizontal-branch (HB) morphology with age and metallicity.

H.-C. Lee, S.-J. Yoon, & Y.-W. Lee (2000, AJ, 120, 998) showed that the popularly used age indicator Hβ index is significantly affected by the presence of blue HB stars. As a matter of fact, because of the systematic HB morphology variation, it is found that Hβ does not monotonically decrease as metallicity increases at given ages but shows a kind of wavy feature. This is because there is a Hβ enhancement due to blue HB stars reaching a maximum strength when the distribution of HB stars is centered around 9500 K, the temperature at which the Hβ index becomes strongest. Comparison of Keck observations of the globular cluster systems (GCSs) in the Milky Way, NGC 1399, and M87 with our new models shows that a systematic shift in the Hβ versus metallicity plane is explained if the mean age of GCSs in giant elliptical galaxies is, on average, a couple of billion years older than the Galactic counterpart. If our age estimation is confirmed, this would imply that star formation in denser environments proceeded much more rapidly and efficiently, so that the initial epoch of star formation in more massive (and denser) systems took place a couple of billion years earlier than in the Milky Way.

Investigation of integrated broadband colors also shows that similar wavy features appear among temperature-sensitive colors, such as $B - V$. Calibration of these model results, especially $B - V$, $V - I$, $C - T_1$, and $M - T_1$, using carefully selected Galactic GCs (i.e., $E(B - V) < 0.2$) is quite remarkable in the sense that the inner halo Galactic GCs do appear older than the outer halo counterparts. It is also noted that $C - T_1$, the well-known highly metallicity sensitive color index, should be used with great caution as a color-metallicity transformation relation if there are age variations within a globular cluster system. Along with Hβ and some temperature-sensitive optical broadband colors, the use of far-UV to optical colors is proposed as the best probe of age for old stellar systems using their HB morphology variation.

SBF colors, such as $\bar{V} - \bar{I}$ or $\bar{V} - \bar{K}$ are found to be almost unaffected by the HB morphology variation because their RGB stars are much brighter than HB stars. However, because HB stars are fairly bright sources compared to RGB stars in the shorter wavelength range, $\bar{U} - \bar{B}$ and $\bar{U} - \bar{V}$ are severely influenced by blue, hot HB stars and differ by ~ 2 mag in our investigated age ranges near [Fe/H] $= -0.5$. Therefore, well-calibrated UBV-band SBF magnitudes for old stellar systems can be a useful stellar population probe as well as a distance indicator. In order for this system to be used for stellar population studies, more observations are clearly needed. It is especially important to obtain a U-band Galactic GC dataset to constrain the effects of post-RGB stars.

Deriving relative ages from photometry alone is complicated by the fact that broadband colors suffer from age-metallicity degeneracy (e.g., G. Worthey 1994, ApJS, 95, 107). Our new models, which come from a consistent code, provide the tools to directly estimate ages of extragalactic GCSs using a variety of theoretical spectrophotometric quantities from far-UV to near-IR. Their use would clearly benefit this field of study. Well-calibrated separate metallicity information from spectroscopy, accompanied by precise spectrophotometry, is neccesary to extract the accurate age information for extragalactic GCSs. When the upcoming spectrophotometric observational data of GCSs in various morphological types of external galaxies from large ground-based telescopes and space-based UV telescopes are compared with our new models, we expect better determinations of the ages and metallicities. This accurate age information will be the most valuable for sorting out the several proposed present day galaxy formation scenarios (merger, accretion, in-situ, etc.). Furthermore, with the best available knowledge of star formation histories and chemical enrichment in galaxies, our models will become the building blocks of composite stellar population models. In the case of galaxy modeling, SBFs could be used as another constraint on stellar population studies in old stellar systems.